Radiation Physics Note 64

The Response of TLD700 ^{7}LiF Thermoluminescent Material to ^{137}Cs γ-ray Exposures between 1 R and 50 kR

R. Dagenais, C. Salsbury, W. Freeman

June, 1987

I. Introduction

This note reports the response versus γ-ray exposure for new TLD700 extruded ribbons manufactured by Harshaw Chemical Company. The data are presented as a response curve that relates the measured response to the true exposure for the annealing and readout cycle commonly used at Fermilab. A future note will present more complete data that includes response curves for various annealing and readout cycles and previous exposure history of the TLD material.

While there exists a large body of data on TLD response to high exposures in the published literature, the details of the particular annealing cycles, readout, and handling techniques are not always clear. The present study was motivated by the use of TLD700 ribbons as integrating dosimeters attached to the CDF detector, as well as use in other beam enclosures where the dose can be large enough so that the TLD material is nonlinear in its response.

II. Experimental Method

Twenty previously unused TLD700 extruded ribbons (0.10 x 0.15 x 0.035 in^3) were randomly selected from a batch of 100 chips supplied by the manufacturer. The chips were annealed at 400°C for 15 minutes and then loaded into a standard Plexiglas tray for a calibration irradiation to check their uniformity of response at low doses. The chips were simultaneously irradiated with 662 keV γ rays from the ^{137}Cs "beam projector" at Site 68 (source 137-8.1-1). The irradiation was at a nominal distance of 100 cm and the delivered exposure was 1 R. Following the calibration exposure, the chips were annealed at 100°C for 15 minutes to remove electrons from the rapidly fading low temperature traps. They were then readout with a Harshaw Model 2000 TLD system. The reading cycle consisted of heating each chip for ten seconds with a laminar flow of 350°C N_2 gas while recording with the 2000B picometer the integrated phototube current from the 2000D reader. The resulting total charge (in nano coulombs) represented the response of each chip. All chips were then reannealed for 15 minutes at 400°C and subjected to test exposures that ranged from 1 R to 50,000 R. The test exposures were made at two source distances: 1.0 m (1 R-500 R) and 19.3 cm (50 R-50000 R). Three overlapping exposures in the range 50 R-500 R were made to check the relative normalizations at the two distances. Following exposure, the usual 100°C pre-read anneal and readout cycle were done for each chip.

III. Results

A. Calibration Exposures

The initial 1 R calibration data are summarized in Fig. 1. The average response for the set of twenty TLDs was 8.85 ± 0.596 nc/R. We note that previous studies have shown batch-to-batch variations in the average response that exceed the in-batch variations.

B. Supralinearity Test Exposures

The results of the test exposures are given in Tables I and II and displayed in Figs. 2 and 3. Each test exposure listed was given to a pair of TLD's and the results for the two chips were averaged. When divided by the true exposure and plotted versus that exposure, the data shown in Fig. 2 result. The open squares are the data taken at 100 cm distance. The filled circles are data taken at 19.3 cm. The maximum deviation from linearity occurs near 10000 R, followed by a sharp decline in response.

As a practical matter, it is most useful to present the data in the manner shown in Fig. 4. The true exposure is plotted as a function of the "measured" exposure, where the measured exposure is defined as the exposure obtained when a linear response is assumed and a calibration factor obtained at low exposure is used to convert the TLD reader output (in nC) to exposure (in R). The measured exposure, so obtained, can then be converted to the true exposure by referring to Fig. 4. The solid curve connecting the data points in the figure can be used to extract the true exposure from the measured one for values between 10 R and ~50000 R. The solid "45^{o}" line represents a purely linear response.

As illustrated in Fig. 2, there was a systematic difference between the nominally identical exposures of 50, 100, and 500 R made at the two irradiation distances of 19.3 and 100 cm. This difference was re-checked with a separate set of four TLDs exposed to 10 R at both distance settings. The 7.8% difference that was found in that measurement was consistent with the difference seen at the earlier higher doses (see Table III) and is suggestive of an offset in the source-to-TLD distance scale. The difference can be entirely explained if the true source-to-TLD distance is 0.85 cm less than the nominal one. An additional source of relative error is any change in the TLD calibration factors between measurements at the two distances. This was typically less than 2%. Effects due to variation (uncertainty) in the irradiation time were negligible. Any variation with distance of the scattered-to-direct components could contribute to an offset in the data. No attempts were made to estimate the importance of this effect in the current measurements, although source geometry consideration would imply that the effect is small for the distance used.

Note that for the data in Figs. 3 and 4 we have corrected downward by 7.8% the data taken at 19.3 cm to account for the apparent distance offset discussed above.

After correction for systematic effects (distance offset), the maximum over response was about a factor of 3.1 at a true exposure of ~10000 R.

IV. Summary

The onset of supralinear behavior in Harshaw TLD700 material was confirmed for our annealing and readout cycle and was quantitatively consistent with other studies. The maximum over response of ~3.1 occurred near 10000 R exposure, but deviations from linearity were measurable above 100 R.

V. References

1. J. R. Cameron, N. Suntharalingam, G. N. Kenney "Thermoluminescent Dosimetry," Univ. of Wisconsin Press, 1968.

2. A. F. McKinlay, "Thermoluminescence Dosimetry," Medical Physics Handbook 5, Adam Hilger Ltd, 1981.

TABLE I

Supralinearity Test Exposure Results (D=100 cm)

Measured Exposure Each (R)	Avg	True Exposure (R)	Ratio ($\frac{\text{Measured}}{\text{True}}$)
1.01			
1.01	1.01	1.0	1.01
5.05			
5.11	5.08	5.0	1.02
10.1			
10.2	10.2	10.0	1.02
51.7			
51.8	51.8	50.0	1.04
108			
105	107	100	1.07
598			
610	604	500	1.22

TABLE II

Supralinearity Test Exposure Results (D=19.3 cm)

Measured Exposure Each (R)	Avg	True Exposure (R)	Ratio $\left(\frac{\text{Measured}}{\text{True}}\right)$	Ratio Corrected
58.8				
55.2	56.0	50.0	1.12	1.04
109				
111	110	100	1.10	1.02
652				
670	661	504	1.31	1.22
1522				
1532	1528	1000	1.53	1.42
13676				
13851	13764	5115	2.69	2.50
40202				
37900	39051	11872	3.29	3.10
52658				
48911	50785	20000	2.54	2.36
66811				
67457	67134	50000	1.34	1.24

TABLE III

Evaluation of Systematic Difference for the Two Nominal Irradiation Distances of 19.3 and 100 cm for 10 R Exposure

TLD No.	Response (19.3 cm)	Response (100 cm)	% Difference
1	92.4	87.3	5.8
2	99.4	93.1	6.8
3	92.1	85.5	7.7
4	83.9	75.6	11.0
Avg			7.8

Figure Captions

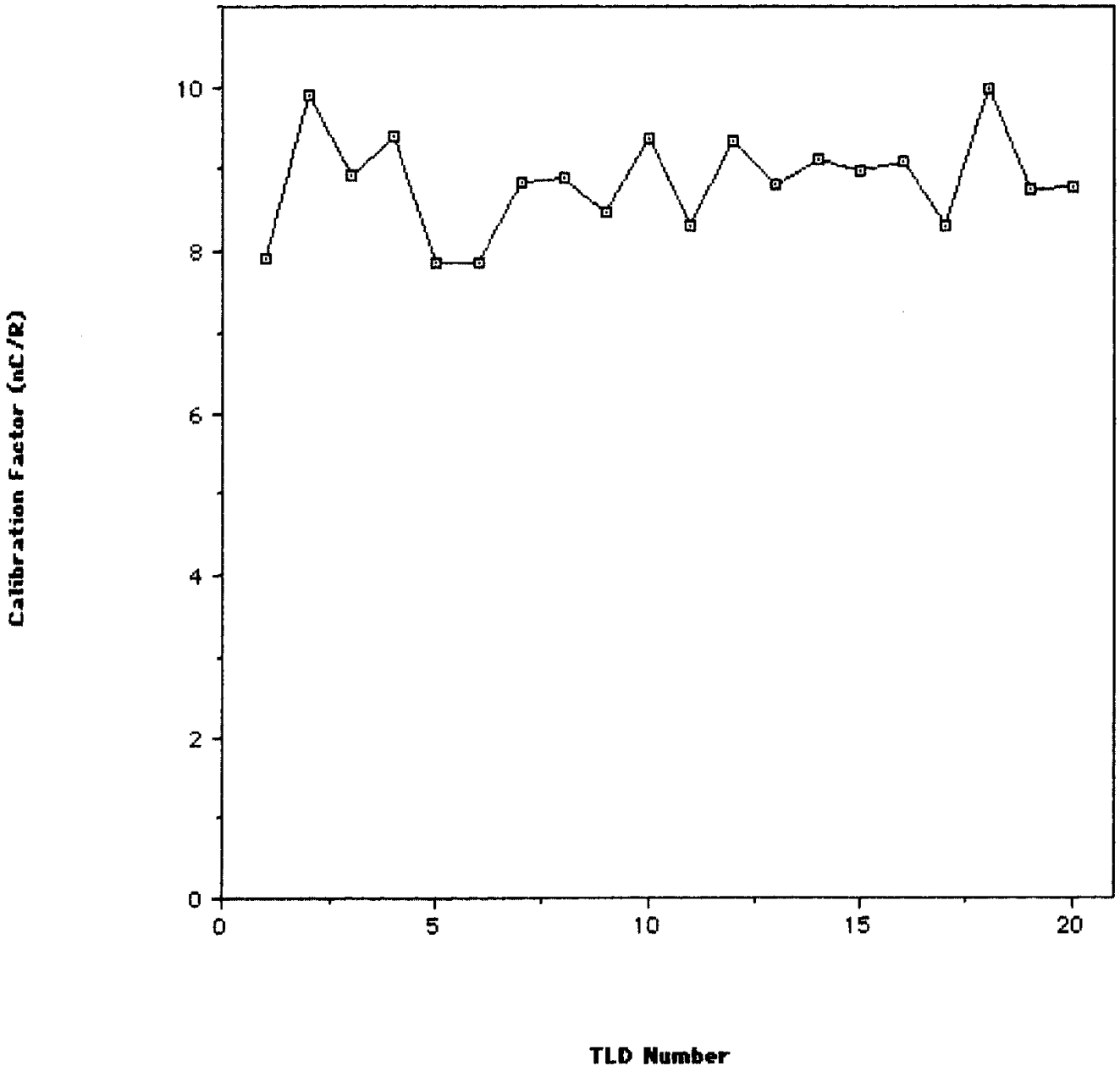
1. TLD700 calibration factor distribution.

2. Deviation from linearity of TLD700 response as a function of the true exposure. Solid points are data taken at nominal distance of 19.3 cm. Open points are data taken at a nominal distance of 100 cm.

3. Same data as in Fig. 2, but with 19.3 cm data corrected downward by 7.8% to account for apparent distance offset in the true source of TLD distance scale. See text for further explanation.

4. True versus measured exposure response as found in this study, using the corrected data of Fig. 3. The solid line connecting the points is used to guide the eye. the plain solid line at 45° illustrates a perfectly linear response.

TLD Calibration Factors (1R Exposure)



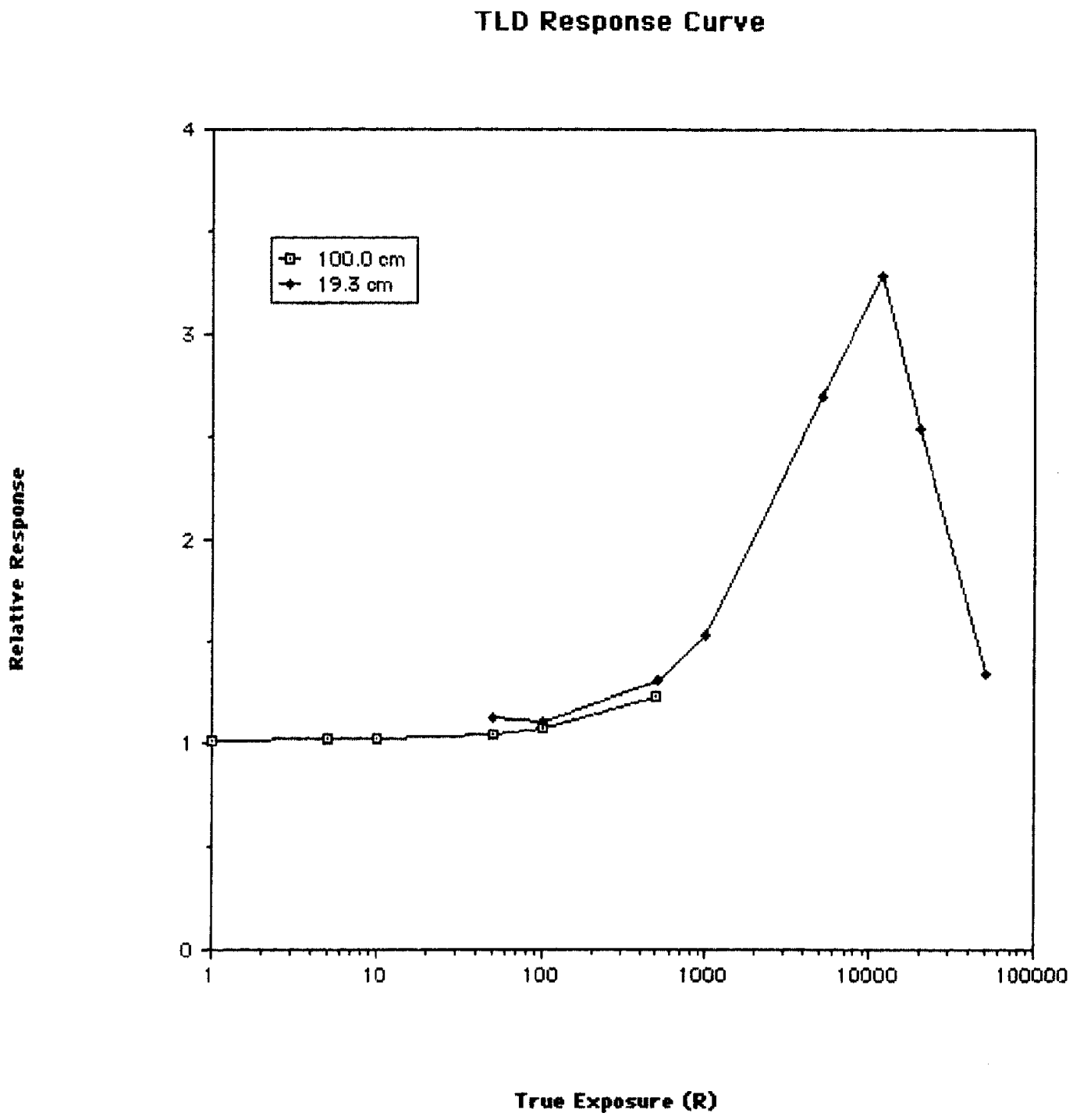
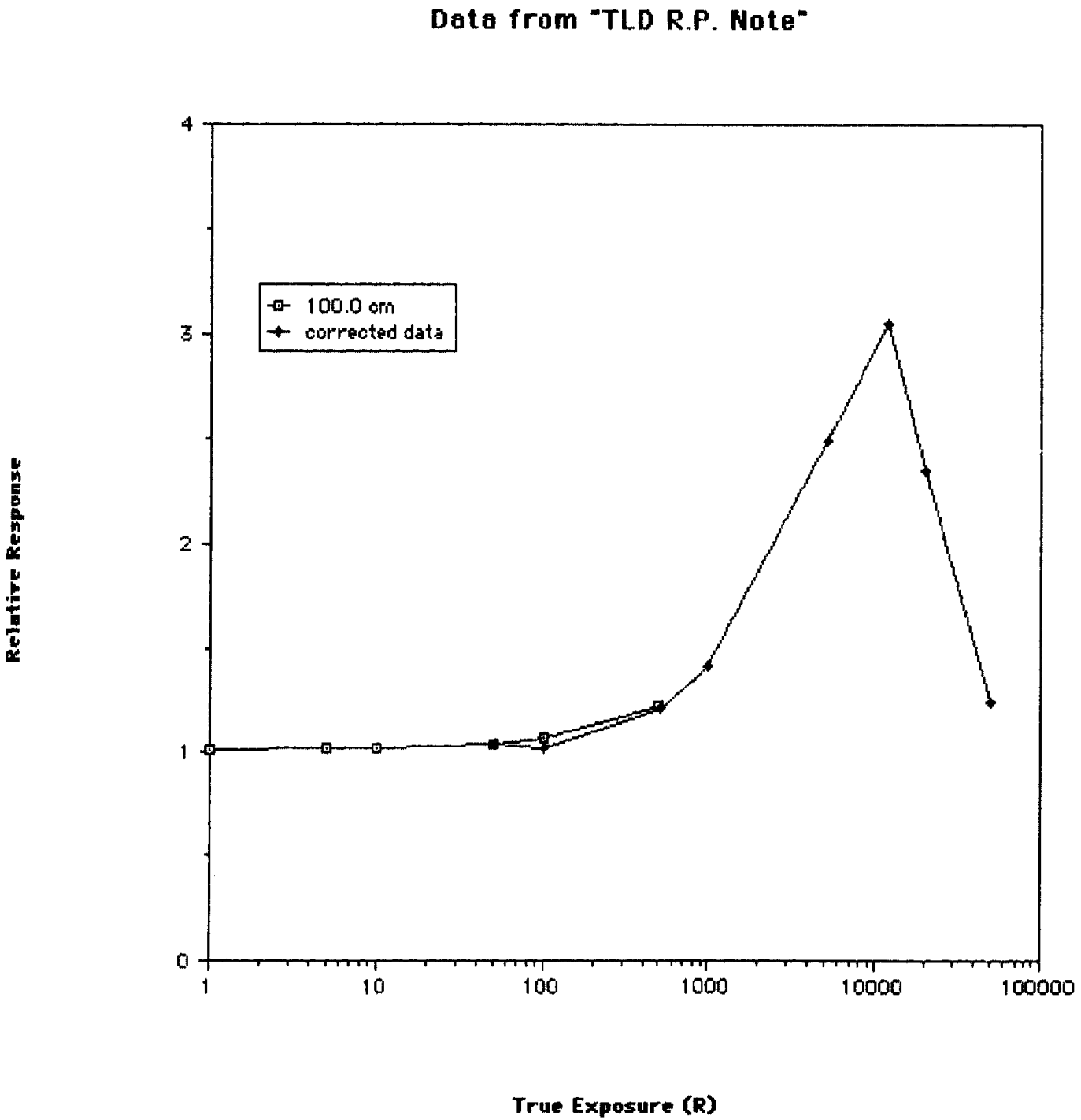

TLD Response Curve
100.0 cm
19.3 cm
Relative Response
True Exposure (R)
0
1
2
3
4
1
10
100
1000
10000
100000

Fig 2


Data from "TLD R.P. Note"
100.0 om
corrected data
Relative Response
True Exposure (R)
0
1
2
3
4
1
10
100
1000
10000
100000

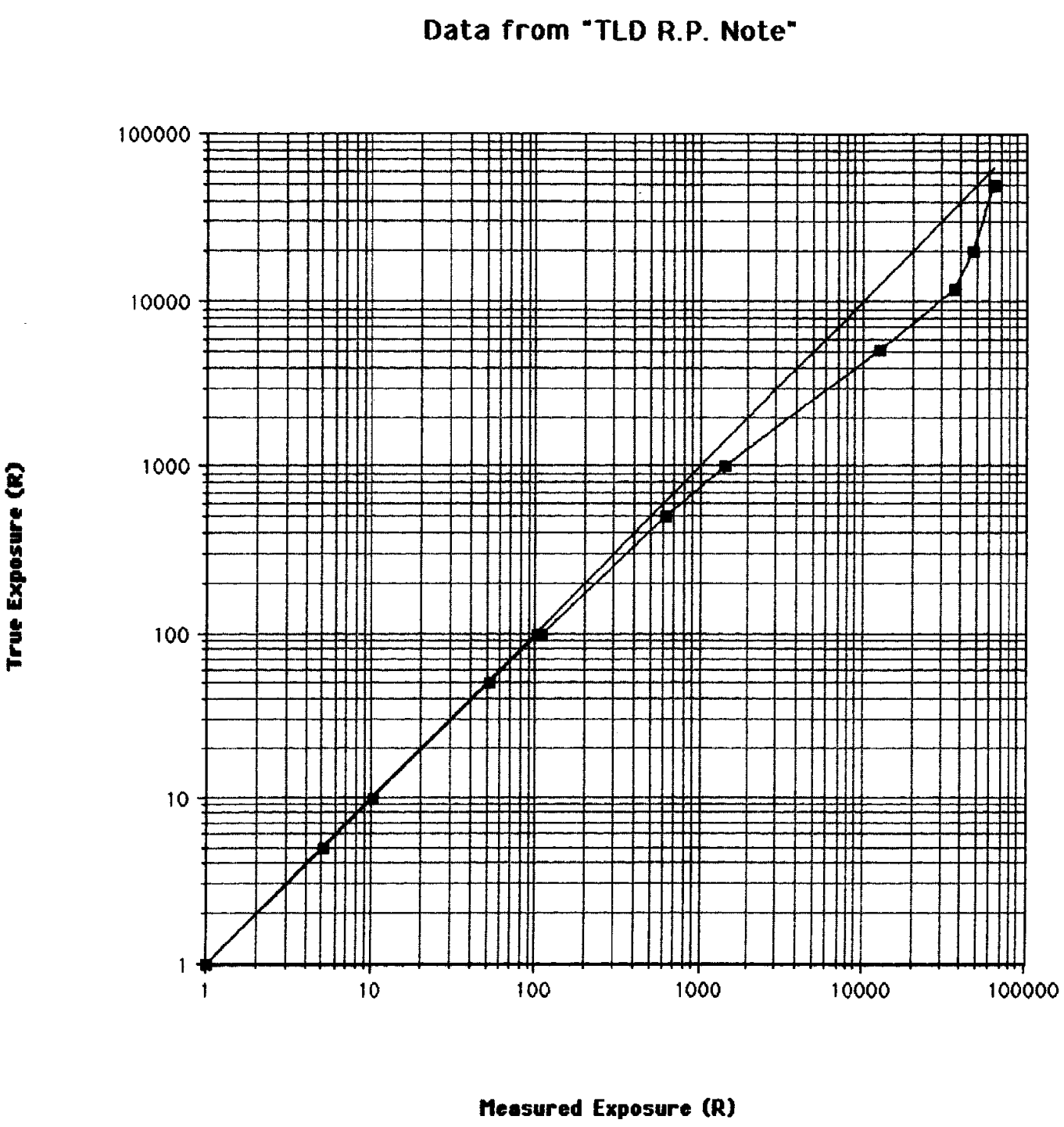

Data from "TLD R.P. Note"
True Exposure (R)
100000
10000
1000
100
10
1
1
10
100
1000
10000
100000
Measured Exposure (R)

Figure 4